GREEN PATENTS AND THE ENERGY TRANSITION: THE ROLE OF INDUSTRIAL INTELLECTUAL PROPERTY IN PROMOTING INNOVATION IN RENEWABLE ENERGY.

PATENTES VERDES E TRANSIÇÃO ENERGÉTICA: O PAPEL DA PROPRIEDADE INTELECTUAL INDUSTRIAL NA PROMOÇÃO DA INOVAÇÃO EM ENERGIAS RENOVÁVEIS.

PATENTES VERDES Y TRANSICIÓN ENERGÉTICA: EL PAPEL DE LA PROPIEDAD INTELECTUAL INDUSTRIAL EN LA PROMOCIÓN DE LA INNOVACIÓN EN ENERGÍAS RENOVABLES.

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ABSTRACT

The energy transition has stimulated the search for solutions capable of reconciling energy security, economic development and environmental sustainability. Within this context,

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renewable energy sources assume a prominent position, while technological innovation and intellectual property protection mechanisms have come to be recognised as instruments for stimulating the advancement of environmentally sustainable technologies. The present study aimed to analyse the role of green patents and industrial intellectual property in promoting technological innovation in renewable energy, highlighting their contribution to the energy transition and sustainable development. The research adopted a qualitative approach, based on a bibliographical review and documentary research, focused on analysing the relationships between energy transition, green patents, technological innovation and industrial intellectual property. The results indicated that green patents constitute an important mechanism for fostering research, development and the diffusion of sustainability-oriented technologies, favouring the legal protection of innovations and the expansion of investments in renewable energy solutions. It was also found that industrial intellectual property contributes to the valorisation of technological knowledge, to technology transfer and to the strengthening of competitiveness in strategic sectors of the economy. It is concluded that green patents and industrial intellectual property play a relevant role in promoting technological innovation in renewable energy, by favouring the protection, valorisation and dissemination of sustainable technologies. The results also demonstrated that the articulation between energy transition, innovation and intellectual protection contributes to strengthening technological competitiveness, sustainability and economic development, consolidating itself as an important support for the construction of energy systems aligned with contemporary environmental challenges.

Keywords: Energy Transition. Renewable Energy. Green Patents. Industrial Intellectual Property.

RESUMO

A transição energética tem estimulado a busca por soluções capazes de compatibilizar segurança energética, desenvolvimento econômico e sustentabilidade ambiental. Nesse cenário, as energias renováveis assumem posição de relevo, enquanto a inovação tecnológica e os mecanismos de proteção da propriedade intelectual passam a ser reconhecidos como instrumentos de estímulo ao avanço de tecnologias ambientalmente sustentáveis. O presente estudo teve como objetivo analisar o papel das patentes verdes e da propriedade intelectual industrial na promoção da inovação tecnológica em energias renováveis, destacando sua contribuição para a transição energética e o desenvolvimento sustentável. A pesquisa adotou abordagem qualitativa, com base em revisão bibliográfica e pesquisa documental, voltada à análise das relações entre transição energética, patentes verdes, inovação tecnológica e propriedade intelectual industrial. Os resultados indicaram que as patentes verdes constituem um importante mecanismo de fomento à pesquisa, ao desenvolvimento e à difusão de tecnologias orientadas à sustentabilidade, favorecendo a proteção jurídica das inovações e a ampliação dos investimentos em soluções energéticas renováveis. Verificou-se, ainda, que a propriedade intelectual industrial contribui para a valorização do conhecimento tecnológico, para a transferência de tecnologia e para o fortalecimento da competitividade em setores estratégicos da economia. Conclui-se que as patentes verdes e a propriedade intelectual industrial desempenham papel relevante na promoção da inovação tecnológica em energias renováveis, ao favorecerem a proteção, a valorização e a disseminação de tecnologias sustentáveis. Os resultados evidenciaram, ademais, que a articulação entre transição energética, inovação e proteção intelectual contribui para o fortalecimento da competitividade tecnológica, da sustentabilidade e do desenvolvimento econômico, consolidando-se como suporte importante para a construção de sistemas energéticos alinhados aos desafios ambientais contemporâneos.

Palavras-chave: Transição Energética. Energias Renováveis. Patentes Verdes. Propriedade Intelectual Industrial.

RESUMEN
La transición energética ha estimulado la búsqueda de soluciones capaces de compatibilizar seguridad energética, desarrollo económico y sostenibilidad ambiental. En este escenario, las energías renovables asumen una posición destacada, mientras que la innovación tecnológica y los mecanismos de protección de la propiedad intelectual pasan a ser reconocidos como instrumentos de estímulo al avance de tecnologías ambientalmente sostenibles. El presente estudio tuvo como objetivo analizar el papel de las patentes verdes y de la propiedad intelectual industrial en la promoción de la innovación tecnológica en energías renovables, destacando su contribución a la transición energética y al desarrollo sostenible. La investigación adoptó un enfoque cualitativo, basado en una revisión bibliográfica y una investigación documental, orientada al análisis de las relaciones entre transición energética, patentes verdes, innovación tecnológica y propiedad intelectual industrial. Los resultados indicaron que las patentes verdes constituyen un importante mecanismo de fomento a la investigación, al desarrollo y a la difusión de tecnologías orientadas a la sostenibilidad, favoreciendo la protección jurídica de las innovaciones y la ampliación de las inversiones en soluciones energéticas renovables. Se verificó, además, que la propiedad intelectual industrial contribuye a la valorización del conocimiento tecnológico, a la transferencia de tecnología y al fortalecimiento de la competitividad en sectores estratégicos de la economía. Se concluye que las patentes verdes y la propiedad intelectual industrial desempeñan un papel relevante en la promoción de la innovación tecnológica en energías renovables, al favorecer la protección, la valorización y la diseminación de tecnologías sostenibles. Los resultados evidenciaron, además, que la articulación entre transición energética, innovación y protección intelectual contribuye al fortalecimiento de la competitividad tecnológica, de la sostenibilidad y del desarrollo económico, consolidándose como un soporte importante para la construcción de sistemas energéticos alineados con los desafíos ambientales contemporáneos.

Palabras clave: Transición Energética. Energías Renovables. Patentes Verdes. Propiedad Intelectual Industrial.

1 INTRODUCTION

The energy transition has become established as a strategic priority of the twenty-first century owing to the need to reduce greenhouse gas emissions, diversify energy matrices and promote development models compatible with contemporary environmental challenges. Within this context, renewable sources assume a central role: they mitigate climate change, reinforce energy security and favour economic and socio-environmental sustainability. In parallel, the growing technological complexity of the energy sector has been stimulating instruments that encourage research, protect innovations and promote the dissemination of solutions for sustainable energy generation.

Among such mechanisms, the so-called green patents and other industrial property instruments stand out, as they contribute to promoting sustainability-oriented technological innovation. By conferring legal protection on inventions relating to renewable energy, these instruments valorise technological knowledge, attract investments in research and development and expand the competitiveness of public and private organisations. Thus, the intersection between energy transition, technological innovation and industrial property constitutes a topic of high scientific, economic and environmental relevance, particularly in view of the global efforts towards the decarbonisation of the economy and the construction of more sustainable energy systems.

In view of this scenario, the present study had as its general objective to analyse the role of green patents and industrial intellectual property in promoting technological innovation in renewable energy, highlighting their contribution to the energy transition and to sustainable development. As specific objectives, the study sought to understand the foundations of the energy transition and the importance of renewable energy for the construction of sustainable energy models; to investigate the concept, characteristics and relevance of green patents as an instrument for stimulating sustainable technological innovation; and to analyse the contribution of industrial intellectual property to the protection, valorisation and dissemination of innovations related to renewable energy.

To achieve these objectives, a qualitative approach was adopted, guided by the critical understanding of the relationships existing between energy transition, green patents, technological innovation and industrial intellectual property. As methodological procedures, a bibliographical review and documentary research were employed, enabling the systematic analysis of the specialised scientific production, as well as of normative and institutional documents related to the investigated topic.

With regard to structural organisation, the article was developed in four main sections. The first corresponds to the present introduction, responsible for the contextualisation of the

topic, the presentation of the objectives and the methodological characterisation of the research. The second section addresses the methodological procedures adopted. The third gathers the theoretical background, in which aspects related to the energy transition, renewable energy, green patents and industrial intellectual property are discussed. Finally, the fourth section presents the final considerations, synthesising the main results obtained and the contributions of the study to the field of renewable energy, technological innovation and intellectual property protection.

2 METHODOLOGY

The debate on green patents and industrial intellectual property in the context of renewable energy takes place within a framework of the search for technological innovations that assist in the energy transition and in sustainable development. Scientific production, in this sense, has aroused a growing interest in understanding the mechanisms that favour the creation, protection and dissemination of technologies aimed at mitigating environmental impacts and reinforcing more sustainable energy matrices. Given the economic, technological and environmental importance of the subject in question, it became necessary to implement methods and procedures that enable a robust analysis of the interrelations between innovation, legal protection and the development of renewable technologies.

The research is of a qualitative nature, as it seeks to understand phenomena, processes, relationships and meanings within the domain of technological innovation and industrial intellectual property in the context of renewable energy. Qualitative research stands out in current scientific investigation, as it allows a critical interpretation of phenomena that cannot be fully understood through quantitative measurements alone. As Guerra *et al.* (2024) point out, this strategy allows a greater immersion in the social, institutional and technological contexts involved, enabling the exploration of the various facets that constitute a specific object of study. The qualitative methodology, in this study, proved appropriate for elucidating the interconnections between energy transition, green patents, technological innovation and sustainable development.

With the aim of achieving the outlined objectives, two complementary methodological procedures were used: documentary research and bibliographical review. The bibliographical review is one of the most widely employed methods in scientific production throughout the world, since it makes it possible to organise, criticise and interconnect the existing knowledge on a specific topic. According to Ocaña-Fernández e Fuster-Guillén (2021), this process is fundamental for elaborating the state of the art, as it enables the detection of concepts, trends, gaps and theoretical approaches that are essential for scientific investigation. The

bibliographical review of this study was grounded in the analysis of scientific articles from specialised journals, book chapters and scientific books dealing with the energy transition, renewable energy, green patents, industrial intellectual property and sustainable technological innovation.

Documentary research is, therefore, an important part of scientific investigation, since it allows the examination of documents produced by governmental institutions, international organisations and specialised entities, serving as complementary evidence to that already present in the academic literature. Documentary research is the technique that enables the obtaining of normative, institutional and historical data that are essential to understanding social, legal, economic and technological phenomena, according to Corrêa, Saramago e Silva (2021). In this context, the following materials were reviewed: Tripla crise planetária: poluição, crise climática e perda de biodiversidade, published by the Programa das Nações Unidas para o Meio Ambiente (PNUMA); the study Transição energética para fontes de energia renováveis e sua dependência por minerais críticos: aspectos geoeconômicos, by Ipea; the document Desafios da transição energética, by the Academia Nacional de Engenharia (ANE); the general statistics on the priority processing of patents made available by the Instituto Nacional da Propriedade Industrial (INPI); the report Mapping Innovations: Patents and the United Nations Sustainable Development Goals, by the World Intellectual Property Organization (WIPO); and Portaria n. 79/2022 of the INPI, which regulates the priority processing of patent applications in Brazil.

The combination of the bibliographical review with the documentary research was appropriate to the objectives of this research, enabling the articulation between theoretical grounding, evidence from institutions, normative data and strategic information on sustainable innovation and intellectual property protection. The bibliographical review, on the one hand, offered the conceptual and analytical foundations indispensable for understanding the topic in question, while the documentary research enabled the examination of guidelines, statistics, regulations and specialised reports that reflect the current dynamics of green patents and the energy transition. Thereby, the combination of these methods enabled a complete, consistent analysis in keeping with the objectives of the study.

3 THEORETICAL BACKGROUND

The theoretical background was structured into three topics, so as to progressively organise the discussion and to offer conceptual support to the development of the research. Initially, item 3.1 addresses the energy transition and renewable energy, presenting their foundations and the main contemporary challenges; subsequently, item 3.2 examines green

patents and their relationship with sustainable technological innovation; finally, item 3.3 analyses industrial intellectual property and its contribution to the promotion of innovation in renewable energy.

3.1 ENERGY TRANSITION AND RENEWABLE ENERGY: CONTEMPORARY FOUNDATIONS AND CHALLENGES

The energy transition is one of the main pillars of the restructuring of current productive and energy systems, resulting from the urgency of reducing greenhouse gas emissions and combating the effects of climate change. In this sense, the increase in the participation of renewable energy is crucial for creating energy matrices that are more sustainable, varied and resilient, aligning environmental, economic and social goals. As Gomes *et al.* (2026) point out, the energy transition is not merely the replacement of fossil sources, but rather a series of geoeconomic, technological and institutional changes that directly impact sustainable development strategies throughout the world and in each country.

This growing concern with energy security and the stability of supply systems increases the urgency of accelerating investments in renewable sources, such as solar, wind, biomass, green hydrogen and small hydroelectric plants. According to Santos *et al.* (2025), the intersection between renewable energy, environmental protection and the green economy is a planned and strategic response to the challenges that the contemporary climate crisis poses to us. This view highlights that energy sustainability is not limited to the mere expansion of the supply of clean energy, but rather to the ability to balance economic growth, environmental protection and social inclusion.

The definition of the Academia Nacional de Engenharia underpins the contemporary understanding of the energy transition. The ANE (2025, p. 01),

> The term Energy Transition (ET) encompasses the process of paradigm shift in the production and use of energy, aiming at the reduction of Greenhouse Gas (GHG) emissions. The great motivation for the ET is the observation of the occurrence in recent decades of relevant climate changes, including the increase in the occurrence of extreme climate effects, whose origin is attributed by most scholars of the subject to human actions, mainly global warming caused by GHG emissions.

This leads us to the observation that the energy transition is deeply interconnected with the worldwide efforts of economic decarbonisation. Barbosa e Gomes (2026) highlight that, owing to the climate commitments of various nations, reducing dependence on fossil fuels has become a priority in the global scenario. From this perspective, the generation of energy from renewable sources helps to reduce emissions, increase the efficiency of energy systems and consolidate development paths that are aligned with global climate goals.

The current literature indicates that the energy transition is neither a linear nor a homogeneous process across countries and regions. According to Schutte e Fuser (2025, p. 09):

> The energy transition is an unequivocal and ongoing process; it will not be curbed given the growing demand for energy. But within this upward curve there are cycles, for the routes of this transition are still under construction and upon them weigh risks and uncertainties that lead sometimes to periods of advancement and acceleration and sometimes to periods of retreat and cooling, but always marching onward.

This perspective offers a clear illustration of how various variables, economic, technological, geopolitical and regulatory, among others, interrelate and play a relevant role in the speed and direction of energy transitions in different national contexts. This illustrates the complexity of the changes taking place in the energy sector throughout the world, where each of these variables is important in shaping the energy future of each nation.

It is of vital importance, when speaking of the challenges of sustainability in the energy sector, to take seriously the growing demand for strategic minerals, indispensable to the development and implementation of technologies for renewable energy. This urgency becomes clearer as sustainable solutions stand out and become crucial in the contemporary world. As Castro *et al.* (2024) affirm, all the equipment needed for the generation of solar energy via photovoltaic systems and the turbines that harness the force of the wind, as well as energy storage systems and smart grids, depend to a large extent on minerals considered essential and critical for the construction and development of the new energy economy. This demonstrates that the energy transition goes beyond technological innovations and advances in technology, also including new configurations and geoeconomic dynamics, which are directly linked to fundamental issues such as the access, processing and effective control of resources considered strategic.

However, before we delve into the analysis of the global and national landscape of renewable energy, it is essential that Table 1 offers a detailed summary of the main foundations and challenges that shape the current debates on the energy transition.

Table 1

Fundamentals and Contemporary Challenges of the Energy Transition

Dimension	Core aspects	Main challenges
Climate change	Reduction of greenhouse gas emissions	Meeting international climate targets
Decarbonization	Gradual replacement of fossil fuels	Technological costs and adaptation of production systems
Energy sustainability	Expanded use of clean and renewable sources	Ensuring continuous and affordable energy supply

Dimension	Core aspects	Main challenges
Energy security	Diversification of energy matrices	Reduction of dependence on external sources
Renewable energy	Expansion of solar, wind, biomass and green hydrogen sources	Infrastructure, storage and integration into the electrical system
Geoeconomics of strategic resources	Growing demand for critical minerals	Dependence on global supply chains
Sustainable development	Integration of economic growth, social inclusion and environmental protection	Balance between competitiveness, sustainability and social justice

Source: Prepared by the author based on Veiga (2019), Castro *et al.* (2024), Santos *et al.* (2025), Schutte and Fuser (2025), ANE (2025), Barbosa and Gomes (2026) and Gomes *et al.* (2026).

The analysis of the international scenario demonstrates that various countries have been structuring policies aimed at the expansion of renewable energy as a strategy to achieve carbon neutrality goals and increase economic competitiveness. However, as Veiga (2019, p. 142) observes,

> A true Green New Deal would induce a change that would lead the central countries to cease being so dependent on the uninterrupted increase in consumption of their populations, simultaneously favouring the take-off of more than a hundred peripheral economies. In other words, one that would generate a strong geopolitical redistribution of global supply and demand, as the more advanced countries sought the paths of a planned prosperity without growth, the only possibility for their economies to become environmentally sustainable. However, it is very difficult to imagine that, under current conditions, political leaders would be led to break with the economic foundations of the last century. The final communiqué of the G20 summit, of April 2009, illustrates this resistance, since, despite some positive formulations on the transition to sustainable economic activities, the concrete measures maintained the traditional economic model.

This assessment makes it clear that the energy transition goes far beyond a simple technological matter; it is, in fact, a series of significant challenges that manifest themselves structurally, particularly in the production and consumption of energy, and that also involve intricate governance issues from a global perspective. Therefore, one must take into account the different layers of challenges that need to be overcome for this transformation to happen in an effective and sustainable manner.

In the national scenario, the forecasts on the energy transition are, without a doubt, optimistic. The main reason is the significant contribution of renewable sources to the country's energy matrix, which is quite robust, together with the fact that Brazil is increasingly integrating itself into the productive chains dedicated to clean energy. This indicates that there is a bright future ahead, signalling the country's commitment to sustainable practices and to the implementation of technologies that favour the conservation of the environment. Brazil has several competitive advantages that are largely related to the abundance of natural resources, the extraordinary capacity for the production of renewable energy and, also, the

opportunities that arise in the context of green hydrogen and other technological innovations. The authors Gomes *et al.* (2026) also emphasise this analysis when discussing the country's potential. Therefore, the consolidation of sustainable energy models is not simply a matter of technological innovation; it is a complex process that involves the interconnection of multiple public policies, the fostering of innovation, productive investment and the creation of efficient mechanisms for the protection of intellectual property. These points are crucial not only to encourage the emergence of new solutions, but also to ensure that these innovations are widely adopted, which is vital for sustainable development and for guaranteeing an energy security that endures over time.

3.2 GREEN PATENTS AND SUSTAINABLE TECHNOLOGICAL INNOVATION

The growing demand for aligning economic growth, environmental preservation and technological progress has raised the importance of green patents in the global context of innovation. These intellectual protections were conceived to promote the creation, development and implementation of technologies that minimise environmental impacts, improve the efficiency in the use of natural resources and help combat climate change. In this sense, green patents have gained prominence in sustainable development agendas throughout the world, especially in areas involving renewable energy, waste management, sustainable transport and energy efficiency (Santos *et al.*, 2026).

The establishment of this legal instrument is intimately linked to the understanding that technological innovation is a crucial element in the shift towards low-carbon productive systems. According to Salgado e Franchi (2023, p. 02),

> Intellectual Property (IP) emerges by exercising a relevant role of incentive to innovation and protection of technology both at the individual or collective level, and at that of companies, universities and research centres, in addition to guaranteeing exclusive rights over the idea that allows the reproduction or use of a product or service, preventing it from being unduly appropriated. It is precisely here that the so-called green patents take place, conceptualised as a type of invention or utility model that contribute to the mitigation or elimination of environmental impacts.

From this perspective, it is possible to understand that the protection offered by patents goes beyond the mere safeguarding of the financial rights of creators and inventors, playing, in a broader manner, a significant role as a mechanism that stimulates the emergence of technological innovations that align with the environmental issues we experience.

The origin of the programmes aimed at green patents is strongly related to the international works that seek to promote sustainable innovation and to the application of climate policies that have the objective of reinforcing global commitments in environmental

matters. These joint initiatives evidence a growing concern with environmental issues and the urgency of creating technologies that help build a more sustainable and environmentally responsible future. Recently, various intellectual property offices have adopted procedures that enable a priority examination aimed especially at innovations that are environmentally sustainable. The reduction in the processing time of registration applications is a direct consequence of this change, which also makes the introduction of these innovations into the market faster. Thereby, the objective is to guarantee not only the protection of these innovations, but also to stimulate the development of solutions that support environmental sustainability. In Brazil, this methodology was officially established by the Instituto Nacional da Propriedade Industrial, or INPI, which created a series of specific procedures to accelerate the analysis of technologies that are considered favourable to the environment. In reports from 2020 and 2022, the initiative was documented, evidencing the institution's commitment to fostering sustainable development through the support of innovations that help preserve the environment.

For a better understanding of the range of technologies that make up the international system of green patents, it is worth observing Table 2, which illustrates the Inventory of Green Technologies promoted by the Organização Mundial da Propriedade Intelectual (OMPI). This illustration evidences, quite clearly, the technological areas most closely related to the issue of environmental sustainability, providing a more comprehensive view of the innovations that seek a healthier and more sustainable environment.

Table 1

WIPO's Green Technologies Inventory.

Quadro 2 - Inventário de Tecnologias Verdes da OMPI.

CLASSES E SUBCLASSES - INVENTÁRIO DE PATENTES VERDES OMPI				
Energias Alternativas	**Transportes**	**Conservação de Energia**	**Gerenciamento de Resíduos**	**Agricultura Sustentável**
Biocombustíveis; Ciclo combinado de gaseificação integrada (IGCC); Células-combustível; Pirólise ou gaseificação de biomassa; Aproveitamento de energia a partir de resíduos; Energia hidráulica; Energia eólica; Energia solar; Energia geotérmica; Produção/uso de calor não derivado de combustão; Utilização de calor residual; Energia mecânica a partir de energia muscular;	Veículos híbridos; Veículos elétricos; Estações de carregamento para veículos elétricos; Veículos movidos por forças da natureza (sol, vento, ondas); Veículos com fonte de potência externa (energia elétrica etc.); Veículos com freios regenerativos; Carroceria com baixo arrasto aerodinâmico; Embreagem eletromagnética;	Armazenagem de energia elétrica; Circuitos de alimentação elétrica; Medição do consumo de eletricidade; Armazenamento de energia térmica; Iluminação de baixo consumo; Isolamento térmico de edificações; Recuperação de energia mecânica (balanço, rolamento, arfagem);	Eliminação de resíduos; Tratamento de resíduos; Destruição de resíduos por combustão; Reutilização de materiais; Controle de poluição; Controle da poluição da água; Prevenção de contaminação radioativa;	Técnicas de reflorestamento; Técnicas alternativas de irrigação; Pesticidas alternativos; Melhoria do solo com fertilizantes orgânicos.

Source: Santos et al. (2026), based on the WIPO Green Technology Inventory.

It is observed that the inventory prepared by the OMPI encompasses a broad set of technologies distributed among alternative energy, sustainable transport, energy conservation, waste management and sustainable agriculture. In the field of renewable energy, technologies related to solar, wind, geothermal, hydraulic, biomass energy and the energy use of waste stand out. According to Santos *et al.* (2026), this classification demonstrates that environmental innovation transcends isolated sectors, constituting an integrated technological network capable of promoting simultaneous gains in economic efficiency and environmental sustainability.

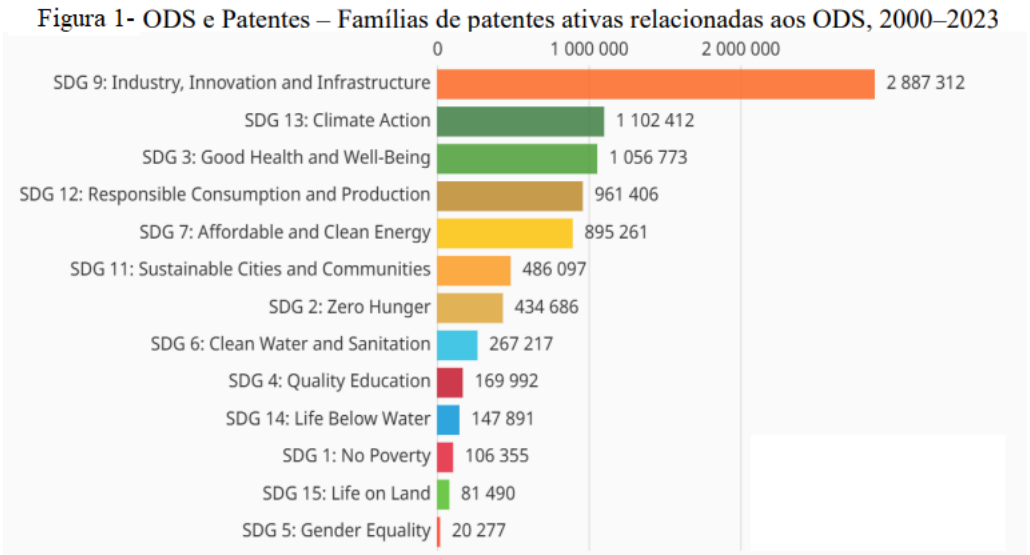
The relationship between green patents and the Sustainable Development Goals (SDGs) has been increasingly evidenced in international studies on innovation. For Santos *et al.* (2026, p. 23):

> While instruments for the protection and incentive of innovation gain ground in the globalised world, in contrast, the need for technologies capable of promoting sustainable development in the face of the climate crisis and socio-environmental challenges intensifies. Companies, universities and public institutions began to incorporate, into their objectives and strategies, aspects linked to sustainability in keeping with the Sustainable Development Goals (SDGs) established by the 2030 Agenda of the United Nations, while needing to remain competitive and innovative.

This convergence between technological innovation and sustainability can be observed in the global distribution of patent families related to the SDGs, as illustrated in Figure 1.

Figure 1

Mapping innovations: patents and the United Nations Sustainable Development Goals



Source: WIPO (2024).

The SDGs of Industry, Innovation and Infrastructure, of Climate Action and of Clean Energy are clearly replete with patent families active around the world. According to the WIPO (2024), this shows that intellectual property structures have been important for driving technological innovations that seek sustainability, the combating of climate change and the updating of energy systems. The growing innovation in the field of renewable energy finds a reflection in patent filings, which accompany the increase in investments in research and development for the generation of clean energy and the reduction of carbon emissions.

Technological monitoring research in Brazil points to an increase, in recent decades, in the interest in technologies that respect the environment. According to Maia *et al.* (2022), there is a growing diversification in the themes addressed in green patent applications, which range from solar energy and biomass to energy efficiency, waste management and industrial technologies that have less impact on the environment. Santos e Martinez (2021) complement this by pointing out that the Brazilian green patent programme helped to increase the visibility of sustainable technologies and to consolidate business strategies focused on environmental innovation.

Green patents not only guarantee the legal protection of inventions, but also promote the diffusion of technical knowledge, making public the detailed information on the invention

processes. This enables companies, research institutions and researchers to use patent documents to carry out technological prospecting, that is, to detect trends, opportunities for collaboration or areas that merit new investments in research and development. Green entrepreneurs face, as Rajkamal, Velmurugan e Suryakumar (2022) point out, issues linked to financing, competitiveness and market insertion, with intellectual property being an important instrument for enhancing sustainable innovation strategies and increasing the capacity for the creation of economic and environmental value. Thus, green patents establish themselves as strategic tools for promoting sustainable technological innovation, facilitating the energy transition and assisting in the creation of development models that address the environmental challenges of the twenty-first century.

3.3 INDUSTRIAL INTELLECTUAL PROPERTY AND THE PROMOTION OF INNOVATION IN RENEWABLE ENERGY

The growing complexity of contemporary energy systems has expanded the relevance of industrial intellectual property as a mechanism for the protection, valorisation and circulation of technological knowledge. In the context of the energy transition, innovation in renewable energy demands high investments in research, development and technological validation, a circumstance that makes indispensable the existence of legal instruments capable of conferring security on inventors, research institutions and innovative companies. In this scenario, industrial intellectual property assumes a relevant role by creating favourable conditions for the generation of technologies aimed at sustainability, energy efficiency and the reduction of greenhouse gas emissions (Herscovici, 2015; Vieira *et al.*, 2023).

Industrial intellectual property comprises a set of mechanisms intended for the protection of intangible assets related to inventive activity, including invention patents, utility models, industrial designs and trademarks. Its purpose surpasses the mere guarantee of economic exclusivity, since it also contributes to the dissemination of technical knowledge through the public disclosure of the information contained in patent documents. From this perspective, the legal protection of inventions favours the dynamics of innovation by stimulating the creation of new products, processes and technological solutions aimed at contemporary energy challenges (Santos & Campos, 2025; Herscovici, 2015).

Santos e Campos (2025, p. 03) assert that:

> Society develops as man creates and develops new technologies and inventions. For this, it is necessary that innovations be applied and protected, so as to protect knowledge and lead to continuity and improvement, contributing so that this cycle of development remains. For this, intellectual property exists.

This shows that intellectual property systems are essential components of knowledge economies. In the energy sector, which faces fierce technological competition and a growing demand for efficiency in solutions, the protection of the results of scientific investigations strengthens innovative environments that are capable of promoting industrial modernisation and the expansion of renewable technologies (Bez & Almeida Junior, 2024; Vieira *et al.*, 2023).

The innovations of the renewable energy sector are, for the most part, protected by invention patents and utility models. Invention patents are aimed at technologies that are new, have inventive activity and can be applied industrially, whereas utility models protect functional improvements in already known objects. Both instruments are essential for the consolidation of technological ecosystems that act in the generation of solar, wind and biomass energy, green hydrogen, energy storage and smart distribution grids, favouring the attraction of investments and the growth of technological markets in a maturation phase (Conceição *et al.*, 2026; Moreira, 2021).

Technology transfer is another element that relates directly to industrial property. The licensing of patents, technological cooperation contracts and the partnerships established between universities, research centres and companies are some of the means that enable the transfer of scientific knowledge to the productive sphere, converting it into practical solutions for production. As Simionato, Silva e Peres (2024) point out, the strategic management of intellectual property enhances technology transfer by reducing legal uncertainties and standardising the conditions for the economic exploitation of the innovations generated in institutional and business environments.

Before presenting the following table, it is important to emphasise that industrial intellectual property performs various functions in the promotion of innovation in renewable energy, integrating legal protection, technology dissemination, competitiveness and economic growth.

Table 3

The Role of Industrial Intellectual Property in Innovation in Renewable Energy

Dimension	Contribution to Renewable Energy	Expected Results
Legal protection	Safeguards inventions and technological improvements	Security for researchers and investors
Stimulus to innovation	Encourages investments in research and development	Expansion of technological production

Dimension	Contribution to Renewable Energy	Expected Results
Technology transfer	Enables licensing and technological cooperation	Dissemination of innovative solutions
Business competitiveness	Differentiates products and processes in the market	Strengthening of competitive position
Economic development	Fosters new businesses and production chains	Generation of employment and income
Energy transition	Supports the dissemination of clean technologies	Reduction of emissions and sustainability

Source: Prepared based on Herscovici (2015), Bez and Almeida Junior (2024), Simionato *et al.* (2024), Santos and Campos (2025), Conceição *et al.* (2026) and Vieira *et al.* (2023).

It is in the energy area that the connection between intellectual property and economic competitiveness becomes clearest, since technological supremacy is, often, responsible for the industrial leadership and for the capacity of countries to insert themselves into the international market. The protection of technological assets is a factor that contributes to the creation of sustainable competitive advantages, since it enables the return on investments in research and the increase in the capacity for constant innovation of organisations. In this sense, intellectual property becomes part of the business strategies that aim at the creation of economic and technological value (Bez & Almeida Junior, 2024; Santos & Campos, 2025).

When it comes, in particular, to technologies that prove to be environmentally sustainable, Conceição *et al.* (2026, p. 02) maintain that:

> Patents and other intangible assets play a fundamental role both in the protection of green technologies and in the stimulus to the development of environmental solutions. The so-called green patents are granted to innovative technologies that promote environmental sustainability, encompassing areas such as renewable energy, energy efficiency and waste treatment. IP fosters sustainable innovation by encouraging the development and dissemination of technologies aimed at the reduction or mitigation of environmental impacts.

This demonstrates that intellectual property, in the industrial field, is not restricted merely to being an instrument of legal protection, but also configures itself as a fundamental tool for driving technological and environmental policies. That is, its importance is not limited to the legal field, but extends to areas that affect both technological innovation and environmental protection. Patent systems are essential for promoting and facilitating the development and dissemination of technologies that may be considered green. In this way, these structures play a fundamental role in accelerating the adoption of solutions that prove to be sustainable in various processes related to production and to the generation of energy. This movement is revealed in the works of Conceição *et al.* (2026) and Moreira (2021).

To conclude, the works and research of the specialised literature indicate that the energy transition will be effective if not only there is the availability and presence of renewable natural resources, but also if there is the capacity to transform scientific knowledge into technological innovations that are not only protected, but that also have economic viability for their implementation. In such a way, it is possible to conclude that industrial intellectual property is of great importance and relevance, given that it is strategic in interconnecting research, innovation, investments and economic development. By fostering the creation, protection and promotion of technologies aimed at renewable energy, this system is crucial for increasing competitiveness in the technological scenario. This action also seeks to increase the sustainability of energy systems and to foster the creation of development models that align with the environmental challenges of the twenty-first century. The studies of Paixão e Abaide (2026), Vieira *et al.* (2023) and Santos e Campos (2025) support this approach.

4 FINAL CONSIDERATIONS

The energy transition ranks among the main contemporary challenges associated with sustainable development, energy security and the confrontation of climate change. In this context, the expansion of renewable energy requires not only the availability of adequate natural resources, but also the creation of environments favourable to technological innovation and to the protection of the knowledge produced. Thus, the discussion on green patents and industrial intellectual property proves particularly relevant, since these instruments contribute to stimulating research, strengthening technological competitiveness and favouring the diffusion of solutions capable of supporting the construction of more sustainable energy systems.

The results obtained allow it to be affirmed that all the objectives proposed in this research were achieved. The general objective, aimed at the analysis of the role of green patents and industrial intellectual property in promoting technological innovation in renewable energy, was fully met by evidencing the contribution of these mechanisms to the energy transition and to sustainable development. Likewise, the specific objectives were contemplated by enabling the understanding of the foundations of the energy transition and of the relevance of renewable sources for sustainable energy models; the investigation of the concept, characteristics and importance of green patents as instruments for the incentive of sustainable technological innovation; and the analysis of the contribution of industrial intellectual property to the protection, valorisation and dissemination of innovations related to the renewable energy sector.

In the development of the first topic of the theoretical background, it was evidenced that the energy transition constitutes a complex and continuous process of transformation of the systems of production and consumption of energy, oriented by the reduction of greenhouse gas emissions, by the expansion of the use of renewable sources and by the search for greater sustainability and energy security. It was also verified that the expansion of renewable energy represents a relevant strategy for confronting climate challenges and for promoting development models compatible with contemporary environmental requirements.

In the second topic of the theoretical background, it was verified that green patents play a significant role as instruments for the incentive of sustainable technological innovation. The analysis carried out demonstrated that these mechanisms contribute to encouraging research and development activities, accelerating the protection of environmentally favourable technologies and expanding the diffusion of solutions aimed at energy efficiency, renewable energy and the mitigation of environmental impacts. It was also found that national and international green patent programmes have contributed to strengthening innovation ecosystems aligned with the objectives of sustainability.

In turn, the third topic of the theoretical background evidenced that industrial intellectual property exercises a strategic function in the legal protection of innovations, in the valorisation of technological assets and in the promotion of technology transfer. The results indicated that instruments such as invention patents and utility models favour business competitiveness, stimulate investments in research and development and contribute to the dissemination of technologies capable of supporting the modernisation of the energy sector and the consolidation of the energy transition.

In view of the results achieved, it is recommended that future research investigate the evolution of green patenting in specific sectors of renewable energy, such as solar energy, wind energy, biomass and green hydrogen. Studies aimed at the analysis of the economic and technological impacts of green patent programmes in different countries are also opportune, as well as investigations on the relationship between intellectual property, international technology transfer and sustainable development. Such approaches may broaden the understanding of the contributions of protected innovation to the strengthening of the energy transition on a global scale.

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